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A CERTAIN TYPE OF LAKE FORMATION IN THE CANADIAN ROCKY MOUNTAINS

In the Rocky Mountains of Canada there are abundant evidences of the great Pleistocene ice invasion. During considerable travel with pack horses through the valleys of the most easterly or summit range the writer had occasion to cross the continental divide by five different passes, from the Simpson Pass on the south to the Athabasca Pass on the north. This gave a familiarity with the range through a degree and one-half of latitude, or from 51° to 52° 30′ N. The evidence was everywhere so constant that a more extended region would undoubtedly reveal the same indications of a former ice sheet.

The general topography of the Rockies in this region is exceedingly rough, the mountains being disposed in long ridges, with peaks from 8000 to over 13,000 feet high, with deep, narrow valleys between.

In order to understand the special type of lake formation to be discussed, it is necessary first to review briefly the general results of former glacial action in the region. These results are evident in the drift, striations and grooves, the transportation of erratics, and in glacial contours.

Drift, consisting of unstratified clay deposits containing angular and glacially striated stones, covers the valleys and passes throughout the region examined. It varies in thickness from a thin layer up to observed sections of more than 300 feet. It is generally thickest in the valley bottoms and on the lower slopes of the mountains up to an altitude of about 500 feet above the stream beds. Above this level it gradually thins out, leaving the mountains bare at from 1000 to 2500 feet above the valleys.

Drumlins occur in many valleys, especially in those now occupied by large streams, and in some regions are so abundant as to become the most prominent feature of the landscape.

The phenomena of crag and tail, like the drumlins, are very constant and no less important in determining the direction of the ice movement. Crag and tail assumes all gradations between ridges several miles in length to those that are merely shallow accumulations of drift in the lee of slight elevations of the rock surface.

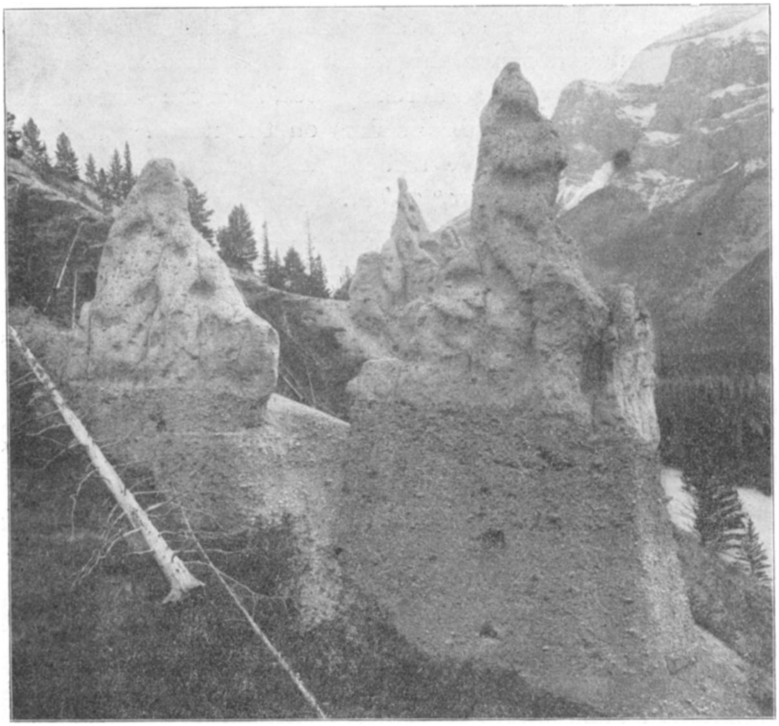


FIG. 1.—Section near Banff showing two tills.

Terminal moraines, except near existing glaciers, are far less frequent than the subglacial drift formations. Modified drift and river terraces are well marked on all the rivers as soon as they reach the plains; also in the mountain valleys of the Athabasca, Saskatchewan, and Columbia; but the smaller rivers and streams rarely show well defined terraces in the mountains themselves.

Several exposures of the drift showed evidence of two ice invasions. One of the clearest of these was discovered on the banks of the Bow River, two and one half miles east of Banff Station, on the Canadian Pacific road. Here the river sweeps against its north bank, and has laid open a section of drift more than 300 feet thick. About half way up the bluff the line between two different kinds of till is clearly marked.

The lower till is of unstratified drift, consisting almost wholly of pebbles and gravel, with but very little clay and rock dust. Quartzite, limestone, and argillite pebbles, many of which are markedly striated, make up the principal mass.

The overlying till consists almost wholly of clay, so hard as to resemble sun-dried brick, which, when struck by a stone resounds like solid rock. Interspersed at considerable intervals are pebbles not differing much from those of the lower till. Like them they are angular and striated. The bottom of these formations is not exposed, as the river rests on drift. However, two formations were later observed on the Cascade River two miles distant, which were identified as the same, and these rested directly on the Cretaceous sandstones of the vicinity. Thus only two tills are represented in this region.

The sides and summits of mountains must be examined for evidence of greater depth in the ice currents than those given by the drift formations. Near the station of Banff, which is in the Bow or South Saskatchewan Valley, about twenty-five miles from the point where the river leaves the mountains, there is a low mountain whose summit is exactly one thousand feet above the river. This mountain is of Devonian limestone throughout, and in form is a blunt ridge running transversely across the valley and partially blocking it. On the top of this mountain there are many Cambrian quartzite bowlders and other erratics which have been transported thither. The nearest point at which these quartzite bowlders are found in place is at Castle Mountain, seventeen miles up the Bow Valley. The limestone ledges are channeled, grooved and striated, in a direction exactly across this mountain, but parallel with the valley.

This mountain, therefore, must have been so deeply covered by a glacial stream that a barrier one thousand feet high caused no deflection of the current.

Proof of higher points being overrun by the ice was observed on Stony Squaw Mountain, which rises to a height of 6130 feet, or 1620 feet above the Bow Valley, and is a little to the northwest of the point just referred to. The mountain has contours rounded by ice action and the higher parts are free from débris or soil except for a few quartzite erratics, of which one, more than two feet in diameter, was found on the very summit. This mountain also is of Devonian limestone formation and consequently the bowlders have been transported hither by glacial action.

The mountains in the neighborhood of Banff show glacially rounded contours much higher than the summits of the lesser points just referred to. Grooves running parallel to the valley direction may be observed on the limestone cliffs of the mountains, from the valley bottom itself, especially in certain conditions of the light. Some of them are between 7000 and 7500 feet above sea level, and indicate that the ice was between 2500 and 3000 feet thick in this region. Up to 7500 feet above the Bow Valley at Banff, the evidence of general ice action is quite certain, but higher than this all is more or less obscure. A distinction must be made between the work done by local glaciers of the mountains and the general currents filling the valleys, but this is not usually difficult as local glaciers, unlike the general currents, were affected directly by the mountain slopes.

Evidence from other parts of the mountains is in accordance with these conclusions. Thus near Lake Louise, forty miles northwest of Banff, in the Bow Valley, striations of a general ice current were found on the summit of a mountain 7350 feet above sea level. Glacial contours are evident about 350 feet higher, or 7700 feet above sea level.

Continuing up the Bow Valley about ten miles, glaciated contours reach an altitude of about 8000 feet. Fifteen miles further up, where the river takes its source, near the Little Fork

Pass, the altitude is still higher, and reaches 8500 feet above sea level. On the other side of the pass in the valley of the Little Fork of the North Saskatchewan, the evidence is almost identical, but with a downward slope of the ice line as the valley descends to the northwest.

The highest erratic was found on a point near Mt. Assiniboine, about twenty-five miles south of Banff, on the summit of a mountain of limestone formation 8650 feet above sea level. In the course of very many mountain ascents no transported bowlders were ever observed at a greater height than this, nor on isolated summits over 9000 feet above sea level were there any evidences of general glacial action.

The indications of former large ice streams which occupied all these mountain valleys are found not only in the Bow Valley but in the tributary valleys of the Saskatchewan and Athabasca on the eastern side of the summit range, and of the Columbia on the western side. In fact no mountain valley was observed in which the same evidence was not more or less apparent, and the line between glaciated and unglaciated surfaces rarely or never appeared at an altitude lower than 7000 feet nor higher than 9000 feet. This ice line is invariably higher in regions of great elevation, near high mountain masses, in elevated valleys and on mountain passes. It is evident then, from the arrangement of drumlins, crag and tail formations, glacial grooves and striations, and the transportation of erratics, that the present drainage system was that of the ice currents, even at the time of their maximum development.

To this there are some interesting exceptions, as for instance, in the Columbia Valley, where it appears that the ice formerly moved southwards and the river now flows northwards. To find a satisfactory explanation is not difficult. This valley is exceptional among the mountain rivers in having very little gradient so that the river is sluggish and the valley is more or less swampy. In other words, it would require only a slight elevation of the region to the north or a depression to the south to reverse the direction of this stream. It is not necessary, however, to assume such a change in elevation, as a slightly greater precipitation in the north would have made this valley discharge its glacier to the south.

We have then, the following, as a summary of the indications of the nature of former glacial activity in this part of the Canadian Rockies:

1. Evidence in the drift formations that glaciers formerly occupied all the mountain valleys.

2. Evidence in certain till exposures that there were at least two distinct ice invasions.

3. Evidence from glacial contours, striations, grooves, and erratics no less than from the absence of them on isolated peaks over 9000 feet high that the former glaciers were between 1500 and 3000 feet in thickness, that their maximum height in the valleys was between 7000 and 9000 feet above sea level, and that the maximum glaciation of this region was always confined to the valleys, above which the very elevated regions and mountains, which were centers of dispersion, rose like islands.

4. Evidence, from the above, that the present drainage system represents approximately the direction of the former ice currents.

Having thus very briefly reviewed the extent of the ice invasion in the Canadian Rockies within the latitude specified, it is now possible to get a clearer idea of the special type of lake basin which is the subject of this article.

Lakes, though very numerous, are limited in size as would naturally be expected in a region of narrow valleys and steep gradients. The two Bow lakes at the sources of the river of that name, are each about four miles long by one mile wide. Outside of these lakes the great majority are smaller and are of all dimensions down to mere pools two or three hundred yards across. About one hundred of these lakes were more or less thoroughly examined and, in regard to their formation, may be divided into four classes.

1. Lakes formed in kettle holes of the valley drift, often in chains of three or four together. In this class should be included

all lakes where water has collected in irregularities of the drift. These are especially numerous near the summits of passes where the nearly level surface has not permitted the streams to cut down and drain the basins. This class of lakes shows no regularity of form or location. Their basins are usually shallow, and they frequently have neither inlet nor outlet.

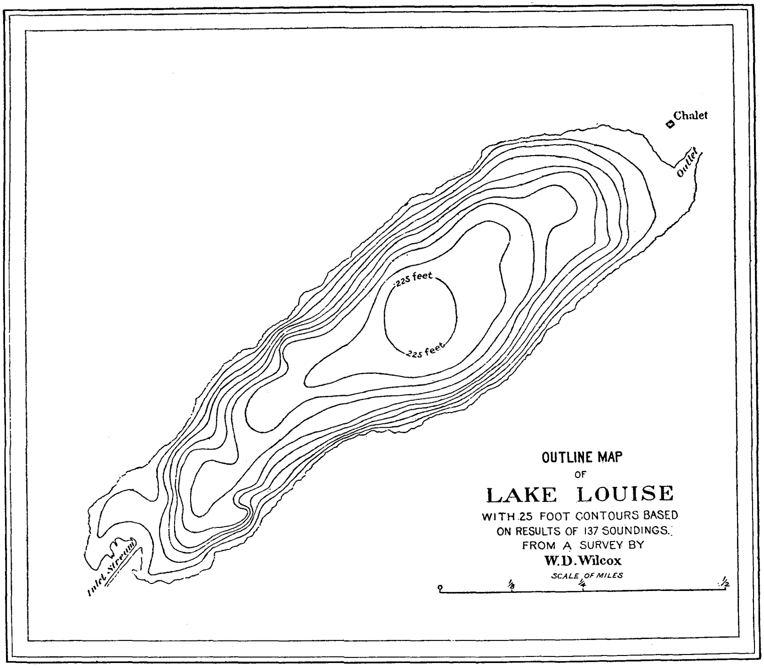


FIG. 2.

2. Lakes dammed by terminal moraines. Only two of these were found distant from existing glaciers. Each was about a mile long and the dam of one was two miles from the end of a large glacier and that of the other about four miles.

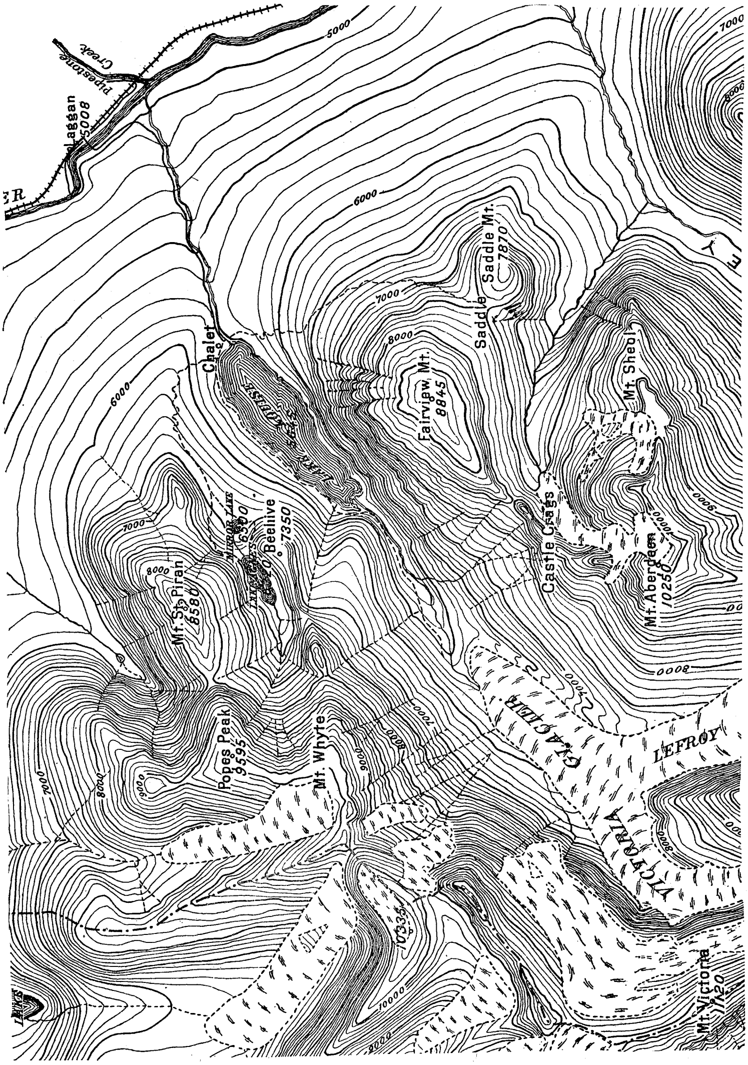
3. Rock basin lakes. Only two of these were observed, one of which was a typical cirque lake. Many rock basin lakes, however, in this region are partially dammed by drift desposits, or are otherwise of complex origin.

4. Lakes found just within the mouths of tributary valleys. These lakes are the most constant of all in their outline and position. They are invariably found where a lesser valley joins a larger one and occupy the mouth of the lesser valley. They are usually leaf-shaped and from three to ten times longer than wide.

Of this type Lake Louise is a good example and was made the subject of special study. Lake Louise is in one of the tributary valleys of the Bow River about twenty-five miles below its source, in latitude 51° 30′ N. and longitude 116° 15′ W. The shore line was carefully surveyed and mapped, after which the basin was studied by means of soundings. The accompanying map of this lake on which the contours represent the depression of the bottom below the surface, shows that the basin is very deep in proportion to its size. The basin is U-shaped with a nearly flat bottom, and with exceedingly steep sides approaching in many places a slope of forty-five degrees.

The lake occupies the end of a valley just above its junction with the much wider valley of the Bow. The catchment basin draining into this lake is an exceedingly rough part of the Rockies, with peaks over 11,000 feet high, forming part of the continental water-shed, at the valley end. The surrounding mountains are covered with considerable fields of ice, which unite to form a glacier about three miles long, measured up either one of its two branches.

A stream from the glacier has carried in clay and gravel so that a delta has formed, and filled in the upper part of the lake basin to the extent of one third of a mile or more. The fine mud carried by the glacial stream which is not heavy enough to sink at once upon reaching the quiet waters of the lake, remains suspended in the lake throughout the summer, and turns its blue-green water to a milky color by the end of August. In November the lake freezes, the inlet stream is much reduced in volume, and becomes clear, and the exceedingly fine mud settles to the bottom. This settling process continues under a thick protection of ice and snow for six months, and with few or no


Pipestone Creek
Laggan 5008
5000
6000
7000
8000
9000
10000
Chalet
Lake Louise
Saddle Mt. 7870
Saddle
Fairview Mt. 8845
Mt. Sheol
Castle Crags
Mt. Aberdeen 10250
Mirror Lake 6550
Lake Agnes
Beehive 7350
Mt. St. Piran 8580
Popes Peak 9595
Mt. Whyte
10335
Victoria Glacier
Lefroy
Mt. Victoria 11420

convection currents to disturb the quiet of the waters, the lake becomes perfectly clear by spring.

An attempt was made to get a section of these clay deposits at the lake bottom and so determine the age of the lake. It seemed probable that by knowing the thickness of the annual deposit, and by getting an entire section, the number of years since the formation of the lake could be estimated. For this purpose a piece of iron pipe about one inch inside diameter was heavily weighted and fastened to a stout rope. This was lowered in about two hundred feet of water and allowed to fall the last fifty feet so as to carry the pipe far into the bottom. Upon lifting the pipe out, and this was accomplished with great difficulty, a core ten inches long was removed from the pipe by drying. Unfortunately this core did not represent the entire section of the lacustrine deposits so that it would have been useless to make estimates on this basis. As had been hoped, however, there were clear evidences of lamination in the slightly different colored bands of clay, though the structure was distorted by being forced into the iron pipe. As nearly as could be counted there were about one hundred bands to an inch, and on the basis of 10,000 years since the last retreat of the ice, these clay deposits would have to be between eight and nine feet thick. With a more perfect apparatus and an entire section, the age of this lake, and consequently the time since the glacial period, might be quite accurately estimated.

The Lake Louise Valley has a trend to the east as it enters the Bow Valley, as though the former ice streams had turned down stream and swept over the flanks of the mountain on the east side of the valley, while the other side shows a sharp ridge of drift descending from the base of a rock buttress 800 feet above the lake. This ridge carries a dam across the valley mouth and slightly deflects the outlet stream to the right. The outlet stream has cut down through this dam and exposed a section of drift from 75 to 100 feet deep. It is typical till of hard, blue clay, with angular or striated limestones, shales and quartzites, distributed through it.

The two valleys to the east which are similar to the Lake Louise Valley in size, direction and general features, have no lakes similarly located, but there is a more or less pronounced drift ridge on the upstream side of each. A swampy meadow in each valley corresponds in position to Lake Louise, and these meadows may represent filled-in lake basins.

Of the very many lakes of the Lake Louise type to be found in these mountains we shall only discuss one that was seen near the continental watershed in about latitude 51° N. at the base of Mt. Assiniboine, a mountain about 12,000 feet in altitude. The lake was small (Fig. 4), probably one third of a mile long, and occupied the opening of a tributary valley to a stream of moderate size. Owing to distance from the base of supplies in this wild region, there was no time to make an examination of the ridge damming this lake, but it was undoubtedly of drift as was indicated by an abundant forest growth upon it. The shape of this lake, the position of the outlet, and the course of the stream deflected by the drift ridge, are clearly shown in the photograph. This lake is typical of this mode of formation.

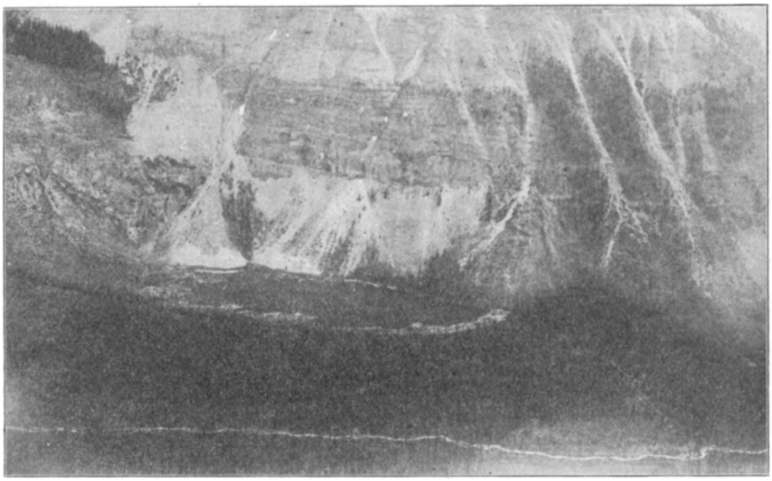


FIG. 4.—Lake near Mt. Assiniboine showing the dam.

A study of many cases showed that a certain ratio between the confluent valleys is necessary to the existence of this kind of lake basin. If the confluent valleys are nearly equal in size, thus showing that the glaciers formerly occupying them were probably of the same dimensions, the drift ridge projects as a long tongue between the two valleys and no basin is formed. If the ratio between the confluent valleys is about three to one or more, the drift ridge is thrown across the mouth of the lesser valley and a lake basin is formed. If, however, the ratio is exceedingly great, the lake basin will either be small, or totally lacking, and will be farther within the lesser valley, as though the lesser glacier had been set back by the great volume of the main ice current.

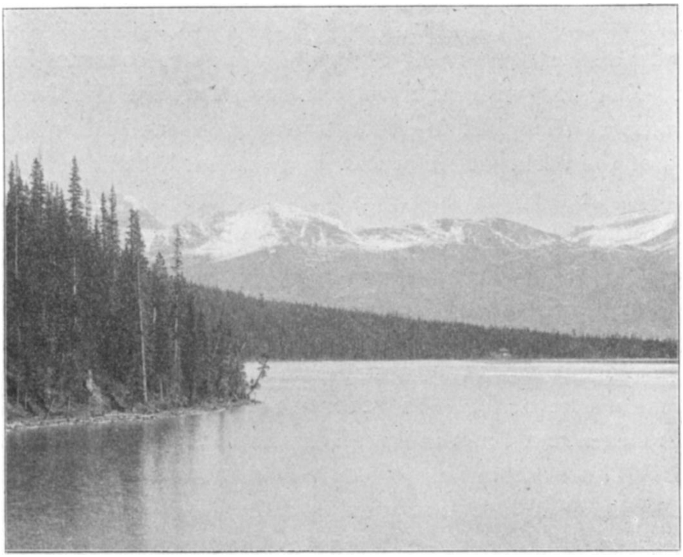


FIG. 5.—Lake Louise from the upper end showing the dam.

Many lake basins of this type have been entirely filled in by deposits of glacial streams and the growth of sphagnum mosses or forests which have made peat swamps or flat meadows where a lake basin formerly was.

So constant is this type of formation, that, upon seeing the ratio between certain mountain valleys, the existence and location of such lakes may be predicted with almost invariable success before the lake has been actually seen. The valley of the Little Fork of the Saskatchewan, which is about thirty miles long, has five streams from the west tributary to the main stream, and every valley has a long drift ridge on the upstream side thrown across the openings of the lesser valleys, resulting in the formation of three lakes and two swamps.

The outline of these drift ridges when looked at from a distance and at right angles to them is quite constant in character. Starting with the rock buttress where the formation commences, the drift is at first very steep and clings to the slopes of the rock. As it continues downward, the slope rapidly decreases in a graceful curve till it approaches an angle of about ten degrees. This slope continues through a great part of its length, only to increase again just before the ridge vanishes as a topographic feature. This curve is represented in almost every one of the many examples observed, and, like the outline of drumlins, may be a mathematical curve depending on the physical nature of ice. In general the outlines of these ridges are smooth like a drumlin or tail formation, and not like a terminal or lateral moraine.

A number of sections were found where streams have cut down through the drift and exposed sections from a few feet up to two or even three hundred feet. In all such cases the formation of the ridges was found to be a regular till without internal arrangement.

The horizontal projection of these ridges is slightly curved, and remarkably similar to what would be the lines of medial moraines on confluent glaciers from such valleys. Moreover these curves are assumed regardless of the lesser topographic forms and thus give another proof that they are not moraines.

To summarize the characteristics of these drift ridges, we have the following:

1. Throughout the valleys of the region under discussion,

and by implication a much more extended area, a certain kind of drift ridge is more or less evident wherever a small valley joins a larger one.

2. These ridges are always found between the confluent streams, are crossed by the lesser stream, and are nearly parallel to the larger valley.

3. They sweep out into the main valley or across the mouth of the lesser one somewhat proportionally to the probable former dimensions of the glaciers occupying them.

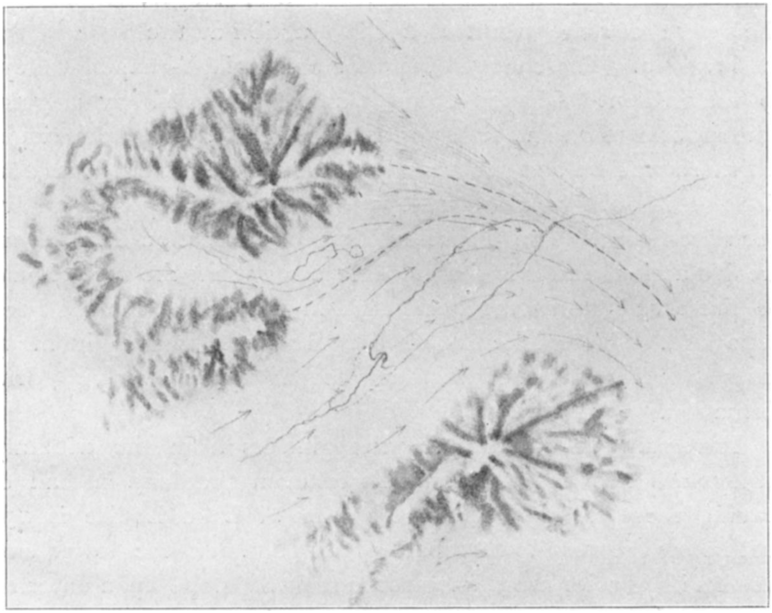


FIG. 6.—Drawing to show probable flow of ice currents from Lake Louise valley.

4. They are of unstratified drift, whose upper ends rest against a rock buttress between the confluent valleys.

5. They have a constant characteristic curve of outline, and of horizontal projection, the latter corresponding to what would be the lines of medial moraines on uniting glaciers from such confluent valleys.

6. They are not sharp crested, but are evidently a subglacial

formation and their direction is not, like terminal or lateral moraines, influenced by minor topographic features.

From the foregoing it seems evident that these drift ridges are a subglacial formation disposed under the ice along the same lines as medial moraines would have had on the glacier surface, and that they are a kind of crag and tail formation resulting from the union of two glaciers. The fact that a rock buttress is the initial point of these drift ridges, shows that they were not the result of a short action at the close of the ice invasion. The change of all the preglacial V-shaped valleys to the present U-shaped form was accomplished by a great amount of erosion and transportation of débris. The rock ridges which commence and probably underlie the drift ridges are portions of the old V-shaped valleys which by their position have been preserved. They represent lines of protection from severe erosive action, and it is therefore necessary that the rock should be preserved along the same line in which the drift has been deposited. These lake basins are therefore possibly in many cases rock basins, but made much deeper by an overlying drift formation.

It remains to inquire why the glaciers from the tributary valleys did not cut out channels of even gradient, instead of leaving these basins. Thus the bottom of Lake Louise is 230 feet below the very lowest part of its dam, and the lower surface of its glacier must have ascended this slope upon entering the Bow Valley. A study of existing glaciers shows that a tributary is always narrower after confluence with a larger glacier as a result of the more rapid movement of the ice current. It is probable that this contraction takes place in the vertical dimensions as well as the horizontal, and thus causes the under surface to ascend, while of course the upper maintains its level.

WALTER D. WILCOX.